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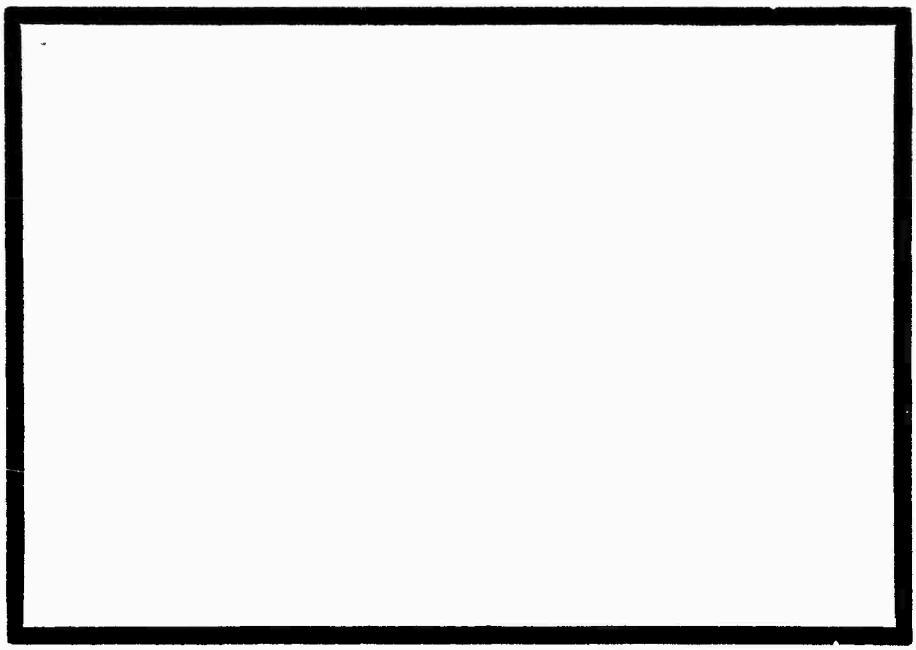

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This annual report describes the year's progress of a research program that will determine the validity of quality metrics of digital imagery and relate these metrics to image interpreter performance with both hard-copy and soft-copy displays. Separate technical reports are issued to cover major elements of work under this contract. This annual report simply summarizes work performed to date.

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INTRODUCTION

Statement of the Problem

Recent technological developments have resulted in a wide variety of imaging systems and subsystems. The flexibility and technology available to the designer include various means for collecting, coding, transmitting, decoding, analog and digital processing, and analog and digital display. The applications of such systems and subsystems are myriad, ranging from static and dynamic military photointerpretive functions, through commercial and closed-circuit television and facsimile systems, to diagnostic radiological instrumentation and earth resources applications. The scientific world is quite familiar with some of the techniques which can be used to "improve" the nature of any such image, and the non-scientific world has equally seen examples of image processing effectiveness, such as the Zapruder and Hughes films of the Kennedy assassination. In many cases, it is clear that such processing and display techniques can extract information in the original image which is otherwise well below the threshold capacity of the human visual system, whereas in other cases it is quite clear that processing techniques can often serve either to hide existing, and important, image detail or to "create" (artifactual) image

detail which is perhaps not present in the original image or in the "real world." Heretofore, most of these areas of image system and subsystem development have plainly suffered from their inattention to human observer requirements. The most visible of these deficiencies is the extensive and expensive developmental effort in digital image processing, particularly that part devoted to the improvement ("enhancement," "restoration") of images for purposes of human information extraction. In nearly all of the work performed in laboratories around the country that are pursuing this type of research, the necessary evaluative efforts to determine the utility of processing and display techniques have not been conducted. Rather, reports and publications of this work typically take the form of "before and after" pairs of images, where the reader is left to estimate the utility of such images either by visual inspection of these published (second- or third-generation) photographs or by the subjective opinions offered in the text by the author.

Because the intent of such image processing techniques is to improve the information extraction capabilities of the human observer, it is clearly appropriate and mandatory that evaluative techniques include objective measurement of human information extraction from such images, rather than merely subjective estimates of the overall quality or utility of the image. Unfortunately, the extraordinary state of

affairs in this scientific realm is that the human factors experiments required to produce quantitative and objective assessment of image quality have rarely, if ever, been measured in image processing laboratories or in conjunction with image processing programs.

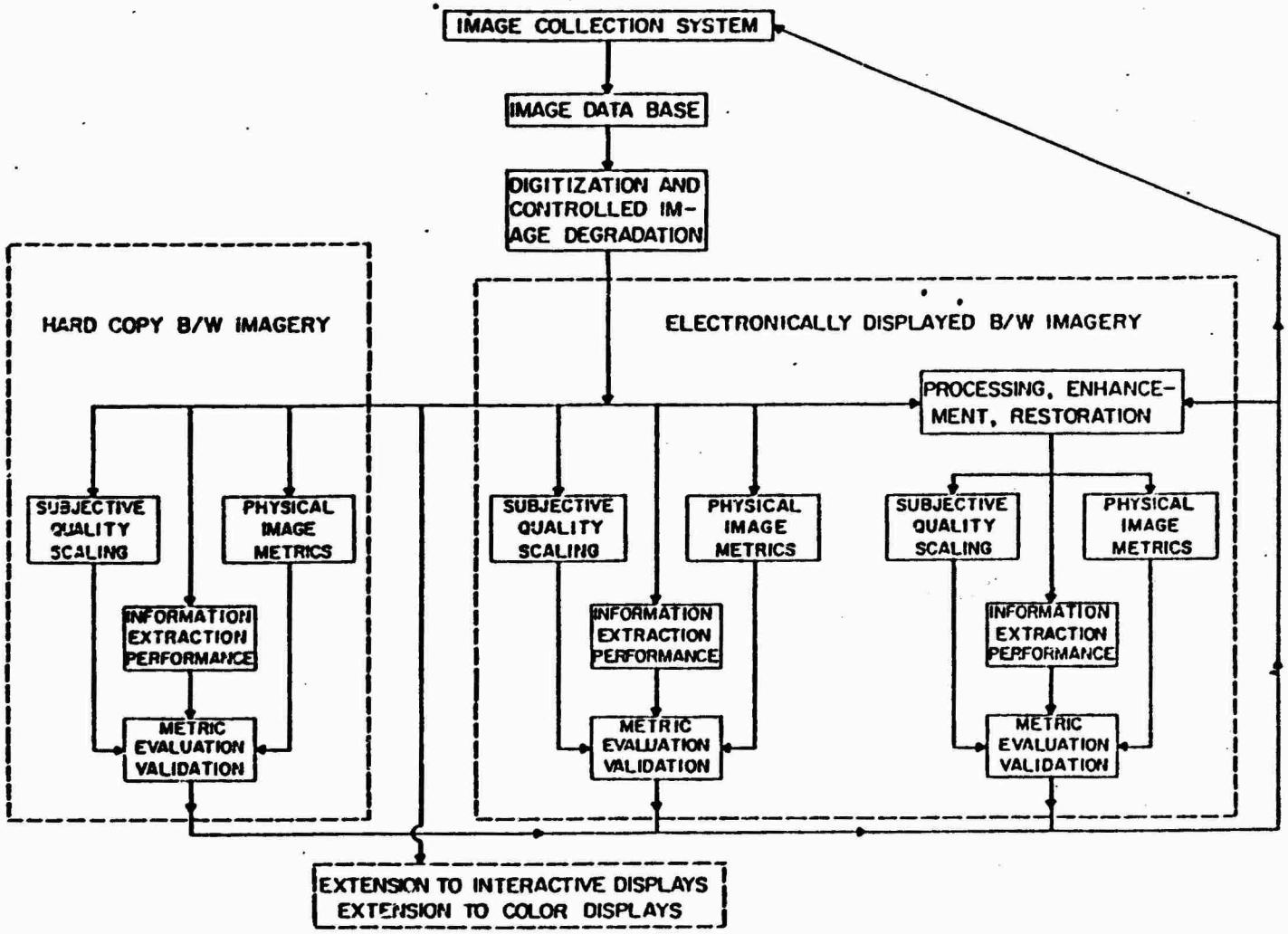
In view of the many millions of dollars being devoted to image collection, processing, and display systems for the military and civilian use of digitized images, it is quite clear that this assessment program is urgently needed to devise procedures, techniques, and metrics of digital image quality. This program includes the establishment of a standardized set of procedures for obtaining human observer information extraction performance; relating this performance, in a quantitative manner, to the various collection, processing, and display techniques and algorithms; and devising a quantitative relationship for the multidimensional scaling of the various collection, processing, and display techniques in "performance space."

Only through such an integrated program of research can the system and subsystem designer have meaningful data for cost-benefit analyses of future system development, be such systems intended either for military or for non-military applications. The image collection, processing, and display technology is now at a point whereby such evaluative research is sorely needed. Fortunately, microphotometric, microdensitometric, and human performance measurement tech-

niques have been evolved during the past several years to relate human information extraction performance to the various physical characteristics of both electrooptical and photographic image displays. The present research program will greatly extend these recently developed techniques into the area of digital images, emphasizing derivation of metrics of image quality appropriate to digitized images, and providing quantitative data which will permit the designer and system developer to plan his developmental effort as well as to specify optimum system components for particular image acquisition and display requirements.

Overview of the Program

The research plan is laid out schematically in Figure 1. Each small, solid-lined box in Figure 1, with the exception of the uppermost, indicates a separate task to be conducted during the course of the effort. The two large, broken-lined boxes delineate the specific display formats that will be studied and compared during the initial program: black-and-white hard-copy transparencies and electronic (soft-copy) displays. The small, broken-lined box at the bottom illustrates important extensions of this research to be pursued in the future, namely interactive digital displays in both black-and-white and full color.



PROGRAM OVERVIEW

Figure 1. Schematic diagram of proposed research

Research Objectives

The research objectives of this program are as follows:

1. Develop standardized procedures and techniques to evaluate hard-copy (film) and soft-copy (CRT) digital image quality.

2. Compare candidate physical metrics of image quality.

3. Compare hard-copy with soft-copy displays for image interpretation.

4. Evaluate candidate processing, enhancement, and restoration algorithms for improvement of image interpretation on soft-copy displays.

To achieve these objectives, the program is broken into 13 interrelated tasks, which are listed below.

Specific Research Tasks

In keeping with the general goals described above, the specific research tasks are as follows:

1. Develop an imagery data base and image intepretation scenarios from high quality aerial photography relevant to the image interpretation task.

2. Select and purchase display and interface hardware to present the image data base on soft-copy (CRT) displays.

3. Develop image manipulation software for soft-copy and hard-copy experiments.

4. Develop and standardize observer data collection procedures for hard-copy and soft-copy experiments.

5. Develop and standardize procedures for obtaining physical image metrics from hard-copy and soft-copy displays.

6. Digitize and degrade data base imagery and record images on hard copy and magnetic tapes for soft-copy display.

7. Obtain physical image metric data for hard-copy and soft-copy displays.

8. Conduct subjective quality scaling and information extraction studies on hard-copy images.

9. Conduct subjective scaling and information extraction studies on soft-copy displays.

10. Evaluate the utility of image quality metrics for both hard-copy and soft-copy imagery.

11. Conduct subjective scaling and information extraction studies on processed soft-copy imagery.

12. Analyze utility of image quality metrics for processed soft-copy imagery.

13. Compare image quality metrics for hard-copy and soft-copy (processed and nonprocessed) images. Relate these results to concepts and models of human visual performance and to imaging system design variables.

STATUS OF THE RESEARCH

Each of the 13 research tasks is listed in Table 1, along with scheduled and/or actual completion dates.

In general, the research is on schedule. Task 1 through Task 8 are complete. That is, preparation for and conduct of all hard-copy studies are complete, and technical reports relating to these studies are in the final stages of preparation and review. It is anticipated that these reports will be published and distributed by 31 March 1981. Preparation is largely complete for the soft-copy study dealing with non-modified imagery, and data collection for this study should begin approximately 15 March 1981, and should be concluded by 30 July 1981. Thus, Task 9 should be completed ahead of schedule, and Task 10 should be completed at least on schedule.

TABLE 1

Schedule and Status

Task	Scheduled Completion	Status or Actual Completion
1. Data base and scenario development	March 1979	June 1979
2. Display and interface hardware	March 1979	March 1979
3. Image manipulation software	Sept., 1979	June 1980
4. Observer data collection procedures	January 1980	January 1980
5. Procedures for quality metrics measurement	June 1980	June 1980
6. Digitize and record data base	July 1980	July 1980
7. Image quality measurements, hard- and soft-copy.	August 1980	December 1980
8. Hard-copy studies	Sept., 1980	September 1980
9. Soft-copy studies	Dec., 1981	to begin March 1981
10. Quality metric evaluation	Dec., 1981	to begin June 1981
11. Processed soft-copy	July 1982	
12. Quality metrics for processed soft-copy	October 1982	
13. Summary analyses	Dec., 1982	

PUBLICATIONS

Several publications are currently in progress. The first technical report to be issued (draft January 1981) will summarize the data collection process and results of the information extraction study of the hard-copy imagery. The second major technical report will describe the experimental process and summarize the results of the quality scaling experiment of the hard-copy imagery. Together, these two reports summarize the work leading up to and including Task 8. In addition, a separate Technical Report will summarize the preparation of, measurement of, and content of the imagery data base (Tasks 1, 3, 5, and 6). The draft of this report will be submitted to AFOSR for review by the end of February, 1981. A separate Technical Report, to be completed by the end of May, 1981, will describe the system for display, manipulation, and data collection with soft-copy displays. While this is not called for as a separate Technical Report in the Statement of Work, it is believed that this particular publication will be very useful for others conducting research in this area, and will serve as a documentary basis for future studies with the soft-copy imagery. Separate Technical Reports dealing with the soft-copy studies conducted during the March-June 1981

time frame will be completed in draft form by the end of September, 1981, and submitted to AFOSR at that time.

PERSONNEL

Faculty

The principal investigators of this research are:

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David I. Shedivy, M.S. (VPI&SU)

James A. Turpin, B.A. (VPI&SU)

Each of these students is a degree candidate doing thesis work under this research program.

INTERACTIONS

In the conduct of this research during the past year, numerous meetings have taken place, formally and informally, with many persons. In addition, the personnel necessary to serve as subjects and to facilitate data collection, as planned, have been provided by both the 460th Tactical Reconnaissance Technical Squadron, Langley AFB, and the 548th Tactical Reconnaissance Group, Hickam AFB. We acknowledge, with great appreciation, the assistance of the following commanding officers of those organizations, both organizations having had a change of command during the past year.

Col. Carl Wiles, Commander, 460th Tactical Reconnaissance Technical Squadron, Langley AFB

Col. David K. Lehnertz, Commander, 460th Tactical Reconnaissance Technical Squadron, Langley AFB

Col. Ronald Markarian, Commander, 548th Tactical Reconnaissance Group, Hickam AFB

Col. John R. McIntyre, Jr., Commander, 548th Tactical Reconnaissance Group, Hickam AFB

Other personnel from each of the above installations have been particularly helpful as well. Through the cooperation of these people and their organizations, arrangements have been made to use Langley photointerpreters for the soft-copy data collection and preparation for hard-copy data collection. In addition, Hickam photointerpreters served for the hard-copy data collection during the months June-September 1980. We especially recognize the contributions of the following persons who devoted considerable effort and time to make this research possible during the past year.

Lt Col. John C. Grimsley, 548th RTG, Hickam AFB
SMSgt Eugene Andrenacci, 548th RTG, Hickam AFB
SMSgt George Pisarek, 460th RTS, Langley AFB
SMSgt Jimmy L. Rogers, 548th RTG, Hickam AFB
MSgt Donald J. Amitrani, 460th RTS, Langley AFB
MSgt Roger L. Cox, 548th RTG, Hickam AFB
TSgt Daryl J. Whitney, 548th RTG, Hickam AFB

As technical monitor, Mr. Gilbert Kuperman has been extremely helpful in providing contacts and advice, and in assisting with the initiation of data collection at the 548th RTG. His advice has certainly made this research more meaningful and useful.

DISCOVERIES, INVENTIONS, PATENTS

No discoveries, inventions, or patents have come from this work to date.

OTHER INFORMATION

The major technical hurdles during the past year were the development of a suitable imagery data base and the collection of photointerpreter performance and scaling data with that data base. While significant technical problems existed, all were acceptably surmounted and the effort was completed on schedule and with satisfactory results. These technical issues and the results are contained in separate technical reports.